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Three-Way Comparison of Selected Substrates Used in Wine Labels: Wood-based Paper, Synthetic Paper, and Stone Paper

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Three-Way Comparison of Selected Substrates Used in Wine Labels:

Wood-based Paper, Synthetic Paper, and Stone Paper

by Sanjana Babu

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Certificate of Approval

Three-Way Comparison of Selected Substrates Used in Wine Labels:

Wood-based Paper, Synthetic Paper, and Stone Paper

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Glossary

Adhesive: "Pressure-sensitive or hear [heat] activated coating used to bond the film to the application surface" ("The basic fundamentals of labeling," n.d., p. 15).

Buckypaper: "A fibrous network made of carbon nanotubes connected through van der Waals forces and physical entanglements" (Mao et al., 2017, p. 9508)

Calcium Carbonate: "Most common natural forms are chalk, limestone, and marble, produced by the sedimentation of the shells of small fossilized snails, shellfish, and coral over millions of years" ("What is Calcium Carbonate?," n.d., para. 1).

Diffuse Reflectance: When light from the incident ray reflects in many angles and directions rather than just one angle, it is called Diffuse Reflection (Choudhury, 2014).

Integrated Sphere: It is a hollow spherical cavity with entry and exit ports made of small holes and the interior coated with a diffuse white reflective coating. It is an optical component with the property of uniform scattering or a diffuse effect ("Integrating Sphere," n.d.).

Mili-newton (mN): "One millinewton is equal to 1/1,000 of a newton, which is equal to the force needed to move one kilogram of mass at a rate of one meter per second squared" ("Millinewton Definition and Usage," n.d., para. 1).

Newton (N): “Unit of force required to accelerate a mass of one kilogram one meter per second, equal to 100,000 dynes" (“Newton [Unit],” n.d., para. 2).

Non-Bibulous: A paper or paperboard that is highly absorbent (“How To Perform Cobb Test On Non-Bibulous Paper And Paper Boards?,” n.d.).

Wood-free paper: Made from chemical pulping rather than from mechanical pulping. In chemical pulping, most of the lignin is eliminated and separated from the cellulose fibers during processing compared to mechanical pulping (“Wood-free paper,” n.d.)

Abstract

Wine labels are one of the most important factors that attract customers to a particular wine bottle. This exploratory study came from an opportunity to expand on the limited material science research published about wine label substrates. It limits its geographic scope to the European and Indian wine label markets. Two synthetic substrates and a stone-based substrate were selected and tested, and their results were compared with test measurements from popular wood-based substrates in this market. When tested, each substrate had an adhesive coating and a liner backing suitable for the substrate. These substrates were tested using six properties: four physical and two optical. A benchmark range was established by considering the highest and lowest measurements of the wood-based substrates. If a substrate property measurement was within the benchmark range or exceeded it in the desirable direction, then that substrate was considered as an alternative for wood-based substrates for that respective property. One of the synthetic substrates (74 Synthetic) was found to be an alternative for four properties tested. The other synthetic substrate (Fasfilm TT) was found to be an alternative for three properties tested. The measurements of stone paper did not indicate that it should be considered as an alternative in any of the tested properties.

Chapter 1

Introduction

Substrates used in printing can vary from paper and plastics to foils and stone. According to *Market Driven Print Quality: What is Good Enough?*(2000) "[The] substrate receives the most attention of all the printing factors when defining a print job due to its potential for introducing variability in the printed page" (p. 32). Other factors include the budgeted cost of the final product and the marketing information used by the paper companies to advertise and sell paper products to designers.

Paper is the primary factor in determining print quality. Paper exhibiting brightness and gloss attracts customers, and weight and textures provide the tactile feel that the customers perceive, making paper a foremost variable for creating an impression. Paper also helps to establish several predetermining factors, such as the maximum print resolution supported, ink laydown, and such similar factors (*Market Driven Print Quality: What is Good Enough?*, 2000).

Importance of Package and Labels

The packaging is one of the main elements that can influence the purchasing decision of nearly any consumer product that is marketed. Characteristics of the package are a part of the product considerations that coexist with other factors of place, promotion, and price: the four P’s of marketing (Kotler & Armstrong, 2012).

Packaging is considered indispensable for both delivery and customer approval of a wide variety of marketed products. It is referred to by Robertson (2012) as a “silent salesman” (p. 4). For a product such as wine, it is necessary that both the outer and inner aspects of packaging be considered. These aspects include the bottle, its color, and shape, along with all the materials and methods used to make the product and its package. A package symbolizes elegance and emotions and acts as a chance to communicate information about the quality of the product and compel the customer to purchase it (Kotler & Armstrong, 2012; Tootelian & Ross, 2000).

Wine packaging consists of many interconnecting elements. Regarding the packaging, one such element is the label. The first ‘label’ was used in the application of small medical containers and appeared around the year 1700. The application of a label at that time was extremely time-consuming as each label was printed using a wooden press on handmade paper and was glued to the product individually (“The history of labels,” n.d.).

Labels can be considered a vehicle that helps in communicating information about the product while also attracting consumers. Depending on the end-use of the product, processes and materials for labels can come in a variety of different styles. The most commonly used materials for wine labels include paper and plastic films and can consist of laminates, fabric, paperboard and metal. Designers of labels employ different strategies for making their labels stand out from others on the shelf (Gomes, 2012).

According to Point-of-Purchase Advertising International (POPAI) (as cited in Clement, 2007), 70% of all purchase decisions for retail products are made in-store. Moreover, 90% of consumers make the decision just by seeing the package without even holding the product in hand (Urbany, Dickson, & Kalapurakal, 1996).

Customization has always been a key attraction to consumers in all sectors. Personalization of wine labels is a new trend that can enhance wine as a personal gift or as a corporate gift at events, trade shows, holidays, and other special occasions ("New Trends in Premium Wine Packaging," 2017). One such website that deals with the personalization of wine bottles is 'personalwine.com,' where the customers can choose the customization of labels from the label's shape to adding photos and messages for special occasions ("Custom Wine Labels," n.d.). One of the most popular examples of customization was the 'Share a Coke' campaign launched in 2011 in Australia, which soon spread to over 70 countries worldwide (McQuilken, 2014). The innovative marketing strategy included switching out the brand logo of the 20-ounce bottle to the most common names of the country where it was being marketed (Tarver, 2019). This campaign resulted in a 7% increase in the ratio of young adult to adult consumption and created a positive image for the brand. It also increased the traffic on the Facebook page by 870%, with 378,000 custom Coke cans printed across the country (Heble, 2019).

An effective wine bottle label has the capability not only to entice the consumers to buy the product but also to make the wine appear attractive on the table. Thus, a label serves as a marketing tool for the product and makes a statement about the purchaser. The label draws a connection between the type of wine purchased and the reputation that the customer wishes to maintain in terms of wine selection (Kidd, 1993).

To ensure a label performs to its intended purpose, it must undergo a series of tests and trials which ensure that the label meets the required quality during processing, storage, and usage (“Packaging Physical and Mechanical Properties Testing,” n.d.). Various industry associations have established technical committees that have developed standard manuals that help in standardizing industry processes. Relevant governing bodies for standard organizations include Tag and Label Manufacturers Institute (TLMI), American Society for Testing Methods (ASTM), Pressure Sensitive Tape Council (PSTC), and the European label association (AFERA and FINAT), which seeks to meet the European standards (Sesetyan, 2005). The Technical Association of the Pulp and Paper Industry (TAPPI) and the International Standards Organization (ISO) are the two important additional organizations that set standards commonly used in industry.

Statement of the Problem

Most of the current research done on wine labels focuses on graphical and marketing aspects, with eye-tracking and surveys chosen as researchers’ methodologies. Several studies (e.g., Elliot & Barth, 2012; Kelley, Hyde, & Bruwer, 2015; Rocchi & Stefani, 2006) focus on the consumer aspect of the selection in terms of preference and perception of wine labels and packaging. Most companies assess the efficacy of the label before it is used on the product. The current study used an exploratory research method that seeks new perceptions and insights about less-explored areas or situations (Robson, 2002). Testing substrates with appropriate adhesive backings for use as wine labels appears to be such an area as no research on this specific topic of inquiry was found. The researchers, Ali (2013), Mao, Goutianos, Tu, Meng, & Yang (2017), and Mota, Meeteren, & Blok (2009), also use methodologies in which paper substrates are compared with regards to their properties as described in more detail in the literature review.

One primary reason for choosing wine labels for this study is the apparent lack of research that has been done in this domain. Given the importance of the wine industry and the critical role that labels play in marketing bottles, it is curious that this area of study has received scant attention from researchers. The topic therefore represents a research area that is both novel and potentially impactful.

In this research, three types of paper—wood-based, synthetic, and marble-based paper—were tested for their physical and optical properties. The outcomes of the tests were then evaluated by comparing the synthetic and marble-based substrates to the outcomes for the wood-based substrates that were used as benchmarks. These comparisons indicated whether the tested synthetic and marble-based substrates achieve optical and physical property measurements comparable to the benchmark range established by the wood-based substrates. As proposed, the results of this study on wine labels can also be applied as a case study relevant for application in other types of beverage labels.

Chapter 2
Literature Review

This section discusses the importance of the wine industry, the importance of the wine labels, the importance of the wine label material, and the research involving similar methodologies.

Importance of Wine Industry

Wine is one of the most popular drinks worldwide. Wine labels play a crucial role in promoting the product, and the quality of design and manufacture of the labels depends on the face stock. This section provides an overview of the production, consumption, the importance of the wine label, the wine label material, and an overview of the methodology. Both the production and consumption sections below are from a global perspective and an Indian perspective. The global perspective is reviewed to give an overall context of the wine industry, and the Indian perspective was chosen for these reasons: (a) the wood-based substrates which were tested in this research were used as the benchmark for the comparison of substrates commonly used for wine labels in India (Akash K S, personal communication with a representative from Avery Dennison, India, August 23, 2019); (b) all of the substrates were made available by Avery Dennison, India; and (c) the testing for this research was done in a lab in India

Production

Wine is consumed in nearly every country, and wine production is an important global industry. The following section describes the production of wine Globally and in India.

Global. The production of wine reached 293 million hectoliters by 2018. Europe is the highest producer of wine, with 70% of the total production of the world. The leading producers of wine in Europe are Italy, France, and Spain, with 51% of the world's production. The other top wine-producing countries are the USA, Argentina, Chile, Australia, and Germany: together, these countries account for 25% of the production. China is an exception here and has reached a point where both the consumption and the production declined in 2018 (Karlsson & Karlsson, 2019). In 2017, wine production recorded an 8.2% decline globally, with Europe having a drop-in production by 14%. There has been a decline in vineyard areas globally since 2014, with the major contributors to the decline being the U.S, Portugal, Iran, and Turkey (Arthur, 2019).

India. The production of wine in India emerged in the 1980's. With wine slowly becoming an important part of the Indian lifestyle, India's wine industry has been showing stable growth over the last ten years. Only 1-2% of the total 123,000 acres of potential vineyard areas are utilized to grow wine in India ("Major Wine Producing Regions of India," 2018).

Maharashtra, Karnataka near Bangalore, and Andhra Pradesh near Hyderabad are some of India's most prominent wine-producing regions. Areas around Baramati, Nashik, Pune, Sangli, and Solapur and the Deccan Plateau are the places where vineyards are found in the Maharashtra region. Frequent pruning, which takes place in February, is required to produce a high yield as a result of the tropical conditions. In Tamil Nadu, Karnataka, and Andhra Pradesh, which are the warm regions, the vines produce crops twice a year ("Wines of India," 2017).

Consumption

Consumption of wine has been growing worldwide. The following section describes the consumption of wine Globally and in India.

Global. The consumption of wine is recorded as stable and estimated at 246 million hectoliters globally. The peak in consumption was recorded between 2007-2008. From the year 2009, consumption has been stable. The five most significant consumers of wine, who represent 49% of the world's consumption, are the USA, France, Italy, Germany, and China. Great Britain ranks in the sixth position, followed by European countries like Russia, Spain, Portugal, Romania, Netherlands, Switzerland, and Hungary (Karlsson & Karlsson, 2019).

India. Wine consumption in India primarily occurs in urban centers. The city of Mumbai consumes the highest percentage with 32% of the total consumption. Delhi

NCR, along with the suburb Gurugram, ranks second with 25% of the consumption, followed by Bangalore at 20% and Pune and Hyderabad at 5% and 3%, respectively (Abernathy, 2018).

Importance of Wine Labels

Labels are said to provide the first impression of wine for a potential purchaser. The label design and its execution are the main factors that consumers consider for the selection of wine if they have not previously tasted it. Consumers want assurances that they are receiving the expected quality when purchasing a bottle of wine. The labels, even though not expensively produced or fancy, must meet quality standards. So if the label is well-executed, even if it is simple, it will echo the quality of wine in the bottle (Slater, 2017). The global market of printed labels in India is increasing to a level to match China. India has shown more significant growth in market share than any other region from 2014 to 2019, with an increase of 7% in the volume that is expected to increase until 2024 ("Label Printing: 2020-2024," 2019).

Researchers (Chrea et al., 2011) have examined the value and differences between three approaches that measure extrinsic product attributes in the selection of Australian wines by consumers. The result from one of the methods indicated that labels were considered to be a strong predictor of choice behavior in selecting wine.

In a similar study, the researchers, Thomas and Pickering (2003), explored the importance of front and back labels together with the importance of an expanded list of information elements. Respondents were asked to indicate the importance of fourteen pieces of information on the wine label using a 7-point rating scale. Eight different versions of two wine types were presented through a mail survey sent to 1,144 participants. A survey sample with a 28% response rate was taken among the staff and students of an academic institution and from a national wine mailing list. Behavioral and demographic information was collected. The results indicated a varied and significant importance level for some wine label elements, such as the front labels were found to be more important than the back labels. The results also showed the wine company and brand name to be more important than the history of the winemaker and the history of the wine region.

In another relevant study, Larson (2012), examined how wine label design can affect the perceptions of the Millennial Generation that is said to comprise a significant segment of the wine market in the U.S. In order to determine the preferred design attributes of the wine labels, the participants underwent two taste-tests and a survey. Results showed that bright colors, more graphically inclined and less traditional label designs, along with creative brand names and also decorative sans-serif typefaces, were the type of wine label designs the millennials preferred, thus supporting that labels and their design are an essential aspect in the purchase of wine by consumers.

Importance of Wine Label Material

Choosing the right substrate for a label is very important. It conveys the brand's vision, the level of performance of the product, and the degree of potential customization of the label. The label materials can be made of paper, film/plastic, or a hybrid substrate, which is a combination of paper and film or even stone. About 50-80% of the wine purchase decisions are based on how the label looks on the bottle. The decoration aspect of a label is also dependent on the substrate. A vital factor to be considered is whether the wine label can remain intact in either wet or cold conditions.

The label made of a paper substrate is the most traditional, giving the label a more natural and classic look. Brands can also choose from linen type paper, paper with a rough texture, or paper that has a velvety feel to it. Embellishments that can be performed on a paper substrate include die-cutting, varnishing, embossing, foil stamping, and also applying a topcoat for protecting the label.

Although a film substrate is more expensive than a paper substrate, it affords some distinct advantages. It can help a brand stand out in a display among other wines made of paper stock. For example, with a film substrate, the labels can be printed on transparent film, thus creating a ‘no label’ look. In addition to transparent films, synthetic substrates are available in metallic or white, giving the brands more options from which to choose.

The hybrid substrate is mostly used for wines that are kept cold in ice buckets. Comprised of a laminate that adheres paper atop film, hybrid substrates help protect the label from the wet and cold environmental conditions of the ice bucket. These hybrid substrates, though best suited for wet and cold conditions, have limitations, such as their high cost and their inability to hold embellishments like embossing (“Choosing the Right Material for your Wine Label,” 2018).

Research Involving Similar Methodology

A search of “paper properties” in ProQuest Dissertations & Theses Global yielded approximately 760 results from studies dating back to 1953 (Thomas, 1953); however, no studies specific to wine label substrate testing were found.

One study that utilized a methodology especially germane to the present research was Ali’s 2013 research that examined copy papers. Ali compared two different types of papers, one manufactured with laboratory-produced precipitated calcium carbonate (PCC) fillers and another manufactured with commercially-produced PCC fillers. These two papers were compared in terms of their mechanical and optical properties to see if the laboratory-made PCC could achieve the same properties as the commercially made one. The tested mechanical properties included Grammage, Caliper, Burst, Tear, Tensile, and Ash. The optical properties that were tested included Brightness, Opacity, and Color. The tests were done using TAPPI standards for mechanical properties and ISO standards for optical properties. A regression analysis with a covariate was used along with a Dunnett Test for making the comparisons between the two papers. The results indicated that there was no statistical difference between the laboratory-made PCC and the commercial PCC. The testing of properties that was done in the current research is similar to that done by Ali (2013). While Ali’s study is methodologically related to the current study, two other studies mentioned below also involved comparisons using property testing between samples.

The two studies are Mao, Goutianos, Tu, Meng, & Yang (2017) and Mota, Meeteren, & Blok (2009). The former compared the fracture properties of three types of papers (cellulose nanopaper, printing paper, and buckypaper [see glossary]) for the purpose of determining if the nanopaper has similar structural integrity compared to the other two. The comparisons were made using the cohesive zone model, which showed that the nanopaper had lower fracture energy than the printing paper and higher fracture energy than the buckypaper. The latter study compared mixtures of vermicompost material (obtained from paper mill sludge and apple waste), green compost from prunings, and a milled baltic white peat. This study aimed to compare the physical properties of vermicompost, peat in mixes, and green compost to determine the ratio to be used in potting media. The results were obtained by an ANOVA analysis which was used to determine relationships among the properties, and a linear regression was used to do correlations and estimations. Although the findings were related to potting soil composition and were therefore not explicitly related to the current study, the method of comparisons of physical properties is similar to the current study.

As previously indicated, much of the published research involving wine labels mainly focuses on the visual aspects of labels and involves surveys and eye-tracking. While there are several studies that compare substrates in other domains, there appears to be limited published research that focuses on the testing and comparison of substrates for wine labels. This study addresses both of these areas.

Chapter 3

Research Objectives

This study sought to answer the following questions regarding the use of three different types of substrates for wine labels:

1. How do the physical and optical properties of selected synthetic substrates compare with those of selected wood-based substrates for use as wine labels?
2. How do the physical and optical properties of a selected stone-based paper compare with those of selected wood-based substrates for use as wine labels?

Chapter 4
Methodology

The main focus of this study consists of a comparison of three types of substrates, wood-based, synthetic, and stone-based, in their application as wine labels. The following section describes the substrates and the tests used in this study.

Substrates

All the substrates used in this research were obtained from Avery Dennison (India). They are representative of substrates often used for wine labels in India and the European regions (Akash K S, personal communication with a representative from Avery Dennison, India, August 23, 2019). Each of these substrates has an adhesive coating and a liner backing that differs from substrate to substrate.

Wood-Based Paper

The following section provides technical details about the three wood-based substrates compared in this study.

Fasson Paper New Black FSC. Designed for wine labels, this full black paper is a core-tinted uncoated matte paper. It features fungicidal treatments and wet strength. The regions where this paper is mainly used include the Middle East, Sub-Sahara Africa, South East Asia, Europe, Chile, North Africa, India, Oceania, and Argentina ("Fasson Paper New Black FSC," n.d.). The adhesive coating used on this substrate is a general purpose rubber-based permanent adhesive (see glossary) used for wine labels. It can stick to a variety of substrates including apolar and slightly rough surfaces. The liner (see glossary) is a supercalendered glassine white paper. Fasson New Black is also used in the primary labeling of high value and premium spirits and specialty foods ("Fasson Paper New Black FSC [AL409]," 2019).

Fasson Canal Blanc New. Designed for wine labels, this paper is a matte wood-free (see glossary) printing paper that is uncoated and white. It features fungicidal treatments and wet strength. The regions where this paper is mainly used include the Middle East, Sub-Sahara Africa, South East Asia, Europe, North Africa, India, and Oceania ("Fasson Paper New Black FSC [AL409]," 2019). The adhesive coating used on this substrate is a special purpose rubber-based permanent adhesive that can adhere to a wide variety of substrates and showcases good performance on bottles at lower temperatures. The liner is a supercalendered glassine white paper. This product is primarily used for labeling of high value and luxury goods, such as wines, spirits, and specialty foods ("Fasson Canal Blanc New FSC [AS571]," 2019).

Estate #8. A white vellum paper with wet strength properties, Estate #8 is specifically designed for wine labels. The adhesive coating used on this substrate is a special purpose rubber-based permanent adhesive for wine labels that, after its application on a dry surface, contributes moisture resistance. The liner is a supercalendered glassine white paper. Estate #8 is suitable for application on a variety of substrates including apolar and slightly rough surfaces. Due to the stiffness of the substrate, it is not suitable for neck labeling applications (“Product Data Fasson Estate # 8 [F29233],” 2009).

Synthetic-Based Paper

The following section provides technical details about the two synthetic-based substrates compared in this study.

Fasson 74µ Synthetic Paper. This paper is a Polypropylene (PP) white matte film. The rubber-based and permanent adhesive used on this substrate is a coating that embodies ultimate bond strength and ultra-high initial tack. The liner is a supercalendered and bleached white kraft liner, featuring high internal strength (Fasson 74µ Synthetic Paper [LM74450], 2016).

Fasson Fasfilm TT Matt White. This paper is a matte white polyolefin film substrate. The adhesive coating used on this substrate is a rubber-based permanent adhesive with good initial tack and ultimate adhesion. The liner is made of a kraft material which is bleached and super calendered with high internal strength (“Fasson Fasfilm TT Matt White [LMD7450],” n.d.).

MarbleBase Paper

MarbleBase (marble-based) is a matte-white durable paper-like substrate made of 80% calcium carbonate (see glossary), one of the most common substances in the world and acquired from marble mining waste, along with 20% of recycled high-density polyethylene (HDPE). These papers are said to be tear-resistant and waterproof and to provide converters with a paper-like material. The adhesive coating used on this substrate is acrylic and a general-purpose permanent adhesive. The liner is a supercalendered glassine paper (*Fasson MarbleBase [BS095]*, 2019; “MarbleBase facestock,” n.d.). Calcium carbonate is not a new substance in the paper world as it has been used as a filler and a coating pigment to provide whiter, brighter, glossier paper for the past 30 years. In the manufacture of MarbleBase paper, the calcium carbonate is the main component of the product, comprising 80% of its composition (Ruggeri, 2017). The HDPE is a non-toxic plastic used to bind the contents of the paper together (“MarbleBase facestock,” n.d.).

Testing

Most of the testing for this research was completed at a pulp, paper, and paperboard mill laboratory located at Erode, Tamil Nadu, in India. Two of the tests were completed at a paper laboratory in North America, USA.

The tests were categorized into two types: physical properties and optical properties. The selection of tests for each property was narrowed down to include only pre-printing properties. All of the tests conducted in the physical property category used the Technical Association of the Pulp and Paper Industry (TAPPI) standards; tests for the optical property category used the International Organization for Standardization (ISO) standards. The choice of standards was determined by the testing laboratories.

Physical Properties

Four physical properties were tested for this research: Burst Strength, Tensile Strength, Tearing Resistance, and a Cobb Test (water resistance). Each is subsequently discussed.

Burst Strength (TAPPI T-403). The Burst Strength measures the resistance of the substrate to the application of pressure perpendicular to the substrate (Ali, 2013; Penttinen, 2012). The Mullen Tester is the equipment most commonly used. This test consists of two steel plates with circular openings. A rubber diaphragm is present in one of the steel plate's opening, which seals a chamber that contains fluid. The substrate is clamped in between the two steel plates. Once the chamber is pressurized, the rubber diaphragm starts to expand and is resisted by the clamped substrate. The pressure is then gradually increased until the bulging diaphragm eventually causes the substrate to rupture. The pressure gauge indicates the pressure that was required for rupture. The unit used to measure Burst Strength is pound-force per square inch (psi) (Caulfield & Gunderson, 1988).

Tensile Strength (TAPPI T-494). The Tensile Strength test measures the maximum force a substrate can withstand per unit width when subjected to a load parallel to the substrate's length. It describes the strength of any substrate (Penttinen, 2012). T-494 simultaneously evaluates three properties of the substrate: tensile breaking strength, stretch or elongation at break, and tensile energy absorption (TEA). The equipment used for this standard (T-494) is termed a constant rate of elongation apparatus. The tensile test helps to determine the structure of the paper. Hence, the individual fiber dimension, elongation, strength, position, and extent of bonding affect the test result (Caulfield & Gunderson, 1988)**.** This test is conducted in both the machine direction (MD) and the cross direction (CD). The unit used to measure Tensile Strength is kilo-newton per meter (kN/m) (see glossary) (Ali, 2013).

Tearing Resistance (TAPPI T-414). Tearing Resistance measures the bonding degree and the strength between the fibers. The "Elmendorf Tear Test" is the most common test method used (Penttinen, 2012). Essentially, this test measures the internal tearing resistance of paper. The force perpendicular to the plane of paper required to tear a single sheet of paper when the tear is already initiated is called internal tearing resistance (Caulfield & Gunderson, 1988). The test is conducted by initiating a cut on one edge of the rectangular sample consisting of about four sheets clamped onto the machine. A 20 mm initial cut is made on all the clamped sheets by a knife attached to the apparatus by a downward swinging pendulum attached to the clamp. The tear of the sheets is fixed at 43 mm, and the energy spent on the tear is measured by the rise of the pendulum

(Popil, 2017). This test is conducted in both the machine direction (MD) and the cross direction (CD). The unit used to measure Tearing Resistance is mili-newtons (mN) (see glossary) (Ali, 2013).

Cobb Test (TAPPI T-441). The Cobb Test is a water absorption test that measures the amount of water absorbed by a non-bibulous paper (see glossary) under certain conditions in a given period of time ("Purpose and Standard Operating Procedure of Cobb Sizing Tester," n.d.). In this test, the substrate to be tested is cut to weigh 0.01g. This substrate is then placed on a rubber mat which is then placed on a metal plate and clamped tightly by placing a metal ring on the specimen to avoid any leakage. Water (100 ml) is quickly poured into the ring, and a stopwatch is used to allow the substrate to sit in the water for 120 seconds, after which the substrate is removed. The excess water from the substrate is removed by placing a blotting paper on it and then using a hand roller with a forward and backward motion to remove water without applying additional pressure. The substrate is then weighed again by folding the sample with the wetted area inside. The amount of water absorbed by the substrate is determined by subtracting the substrate weight before testing from the substrate weight after testing. The substrate will be rejected if liquid passes from the substrate to the rubber mat or if there is any leakage. This test is conducted on both the top side (TS) and the wire side (WS) of the substrate. The unit used to measure water absorbency is g/m2 ("Water absorptiveness … T 441 om-09," 2013).

Optical Properties

Two optical properties were tested for this research: Brightness and Opacity. Each is subsequently discussed.

Brightness (ISO 2470). The Brightness test helps in determining the brightness of naturally colored, near-white, and white pulp, paper, and paperboard ("Brightness of pulp, paper, and paperboard [directional reflectance at 457 nm], Test Method T452 om-18," 2018). ISO 2470 is used in Europe and other parts of the world for the specification of paper brightness. In ISO 2470, the light source used to illuminate the samples contains a certain amount of U.V. energy and is called CIE illuminant C, a daylight illuminant. In this standard (ISO 2470), the samples are illuminated by two lamps in the instrument that project the light into an integrated sphere (see glossary). The light inside the sphere inter-reflects as the sphere is coated with a highly reflective and non-glossy substance allowing the sample to be illuminated in all directions. The spectral power distribution of the reflected light is measured, and the energy response is quantified at 457 nanometers. The unit used to measure Brightness is a percentage (%) reflected light ("Understanding Paper Brightness," 2017).

Opacity (ISO 2471). An Opacity test is used to determine the amount of light absorbed by a substrate (Kipphan, 2001). According to Scott et al. (as cited in Hubbe, Pawlak, & Koukoulas, 2008), the ability to hide whatever is printed on the backside of paper or a successive sheet is called the opacity of the paper. In the ISO 2471 standard, a light with a 557 nm wavelength is passed through the sample by diffuse reflectance (see glossary). The diffuse opacity is then measured from the diffuse reflectance (Hubbe et al., 2008). This standard requires two plates that are made of ceramic, flat opal glass, or other suitable material. A black cavity with the reflectance value of not more than 0.2% is stored upside down and protected from contamination. The substrate to be tested is cut into rectangular pieces measuring approximately 75 mm x 150 mm. The substrates are then stacked on the pad with at least ten substrates in quantity with the top side up. For testing the substrate, the sheet covering the pad is removed. The substrate is then placed, and the intrinsic luminance factor of the top of the substrate is measured. The reflectance value nearest to the 0.01% is read and recorded ("ISO 2471:2008[en] Paper and board — Determination of opacity [paper backing] — Diffuse reflectance method," 2008). The opacity of a substrate depends on the amount and type of filler, thickness, the level of bleaching of fibers, and similar factors ("TAPPI T 425 Opacity, Directional Geometry," n.d.).

The results of property testing for synthetic and marble-based substrates were then compared to the benchmark range established for the wood-based substrates, which represent the most commonly used material for wine labels in India. Thus, the results should be helpful in determining the appropriateness of the synthetic and marble-based paper for possible wine label applications.

Chapter 5

Results and Analyses

This chapter discusses the results of the physical and optical property tests that were performed on the substrate samples listed in Table 1. This chapter also contextualizes the results in detail in regards to each of the research questions, as stated in Chapter 3 and summarized below:

1. Synthetic paper v. Wood-based paper
2. Stone paper v. Wood-based paper

Tests of Physical and Optical Properties

This section describes the objective of each test and identifies its numerical measurement.

Physical Properties

The physical properties tested were Burst Strength, Tensile Strength, Tearing Resistance, and the Cobb Test. All of these tests were performed using the TAPPI standards as shown.

Burst Strength (TAPPI T-403). Burst Strength measures the resistance of the substrate to the application of pressure perpendicular to the substrate (Ali, 2013; Penttinen, 2012). For Burst Strength, a higher score is desirable (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). Burst Strength is measured in pound-force per square inch (psi).

Tensile Strength (TAPPI T-494). Tensile Strength measures the maximum force a substrate can withstand per unit width when subjected to a load parallel to the substrate's length. It describes the stress required to break a substrate through stretching (James, 2017; Penttinen, 2012). For Tensile Strength, a higher score is desirable (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). Tensile Strength is measured in Kilo Newtons per Meter (kN/m).

Tearing Resistance (TAPPI T-414). Tearing Resistance measures the bonding degree and the strength between the fibers (Penttinen, 2012). For Tearing Resistance, a higher score is desirable (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). Tearing Resistance is measured in mili-Newtons (mN).

Cobb Test (TAPPI T-441). A Cobb Test is a water absorption test that measures the amount of water absorbed by a non-bibulous paper under certain conditions in a given period of time ("Purpose and Standard Operating Procedure of Cobb Sizing Tester," n.d.). For a Cobb Test, a lower score is desirable (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). The Cobb Test is measured in grams per meter squared (g/m^2).

Optical Properties

The optical properties tested were Brightness and Opacity. These tests were performed using the ISO standards as shown.

Brightness (ISO 2470). The Brightness test aids in determining the brightness of naturally colored, near-white, and white pulp, paper, and paperboard ("Brightness of pulp, paper, and paperboard (directional reflectance at 457 nm), Test Method T452 om-18," 2018). The desired brightness of substrates is often aesthetically dependent on the design of the wine labels. Brightness of a paper is calculated on a scale of 0-100, where the higher the number means the higher the brightness (Rogers, 2015). Brightness is measured in percentage (%) reflected light.

Opacity (ISO 2471). An Opacity test is used to determine the amount of light absorbed by a substrate (Kipphan, 2001). According to Scott et al. (as cited in Hubbe, Pawlak, & Koukoulas, 2008), the ability to hide whatever is printed on the backside of paper or on a successive sheet is called the opacity of the paper. For Opacity, a higher score indicates increased opacity (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). The desired opacity of substrates is often aesthetically dependent on the design of the wine labels.

Substrates and Measurement Outcomes

In this section, shortened names of the sample substrates are used; these are identified in Table 1.

Table 1

Substrate Names and Referred Name

Substrate Name	Shortened Name
Fasson Canal Blanc New	Canal Blanc
Fasson Paper New Black FSC	Paper New Black
Estate #8	Estate 8
Fasson 74µ Synthetic Paper	74 Synthetic
Fasson Fasfilm TT Matt White	Fasfilm TT
MarbleBase Paper	Stone-based

The outcomes of all the tests, both physical and optical, are shown in Table 2. All the values are approximate values due to the adhesive backing present on every tested substrate.

Table 2

Sample Measurements

Sample	Burst Strength (psi)	Tensile Strength (kN/m) MD/CD	Tearing Resistance (mN) MD/CD	Cobb Test (g/m^2) TS/WS	Brightness % Reflection	Opacity % Transmission
Canal Blanc	69.51	9.32/5.2	120/124	24/32	83.11	94.81
Paper New Black	64.01	5.5/5.0	122/126	21/22	4.04	99.9
Estate 8	64.13	9.2/8.5	145/152	30/22	86.39	93.32
74 Synthetic	-	9.6/5.6	125/131	35/25	89.35	93.51
Fasfilm TT	-	5.4/3.5	130/134	1/18	89.53	90.44
Marble Base	47.99	5.9/3.8	54/60	4.6/26	82.13	92.43

Discussion of Research Questions and Analyses

The following section discusses the outcomes of each of the substrate tests, and then using these data addresses each Research Question.

Research Question 1

How do the physical and optical properties of selected synthetic substrates compare with those of selected wood-based substrates for use as wine labels?

Physical Properties

Burst Strength. As shown in Table 2, the Burst Strength of synthetic substrates could not be determined. During the test, the substrates stretched and did not burst. Another testing instrument or method should be identified and used to measure the synthetic substrates. This suggests that Burst Strength itself is not a defining factor in choosing between wood-based and synthetic papers; however, the readiness of synthetic papers to stretch may be a factor that needs to be further tested and investigated.

Tensile Strength. Tensile Strength is measured in the Machine Direction (MD) and the Cross Direction (CD). As Figure 1 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8 have Tensile Strength in the Machine Direction (MD) of 9.32 kN/m, 5.5 kN/m, and 9.2 kN/m, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Tensile Strength in the MD of 9.6 kN/m and 5.4 kN/m, respectively.

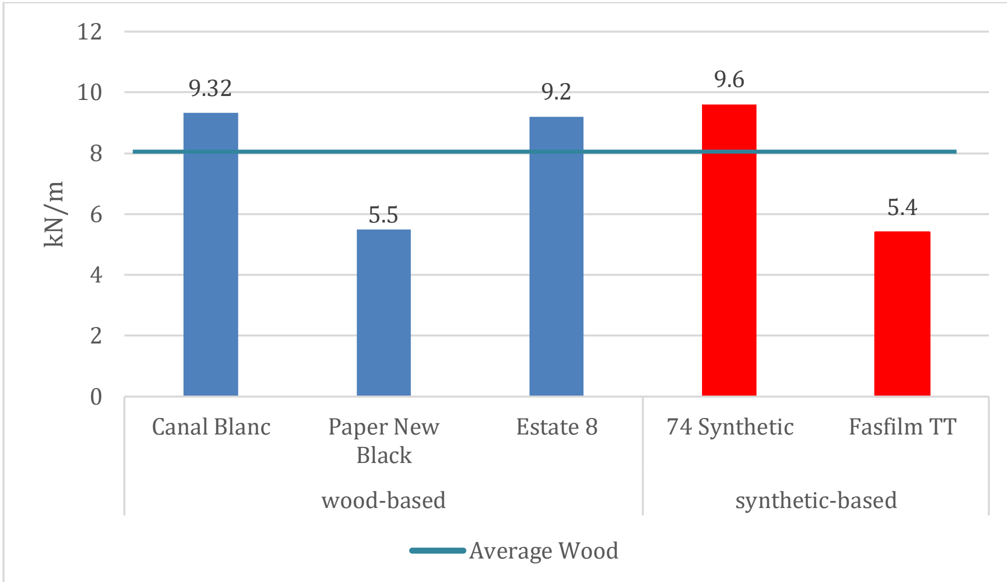

Figure 1. Tensile Strength (MD) of Synthetic v. Wood

The Tensile Strength (MD) of the synthetic substrates falls outside the benchmark range of wood-based substrates, with one synthetic outperforming the wood-based substrates and one underperforming all three of the wood-based substrates. This suggests that a particular synthetic substrate, 74 Synthetic, could perform effectively in terms of providing a desired Tensile Strength similar to that of wood-based substrates.

As Figure 2 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tensile Strength in the Cross Direction (CD) of 5.2 kN/m, 5 kN/m, and 8.5 kN/m, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Tensile Strength in the machine direction of 5.6 kN/m and 3.5 kN/m, respectively.

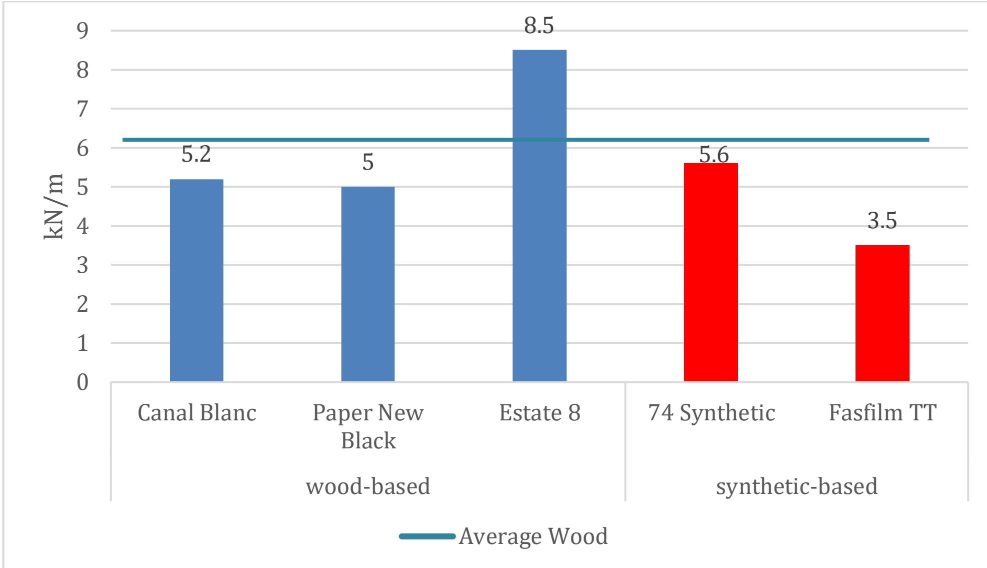

Figure 2. Tensile Strength (CD) of Synthetic v. Wood

The Tensile Strength (CD) of one of the synthetic substrates, 74 Synthetic, falls within the benchmark range of wood-based substrates; whereas, the other synthetic substrate, Fasfilm TT, falls outside the lower benchmark range of wood-based substrates. This suggests that 74 Synthetic could be a comparable substrate to the wood as it is positioned within the benchmark range.

Tearing Resistance. Tearing Resistance is measured in the Machine Direction (MD) and Cross Direction (CD). As Figure 3 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tearing Resistance in the Machine Direction (MD) of 120 mN, 122 mN, and 145 mN, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Tearing Resistance in the MD of 125 mN and 130 mN, respectively.

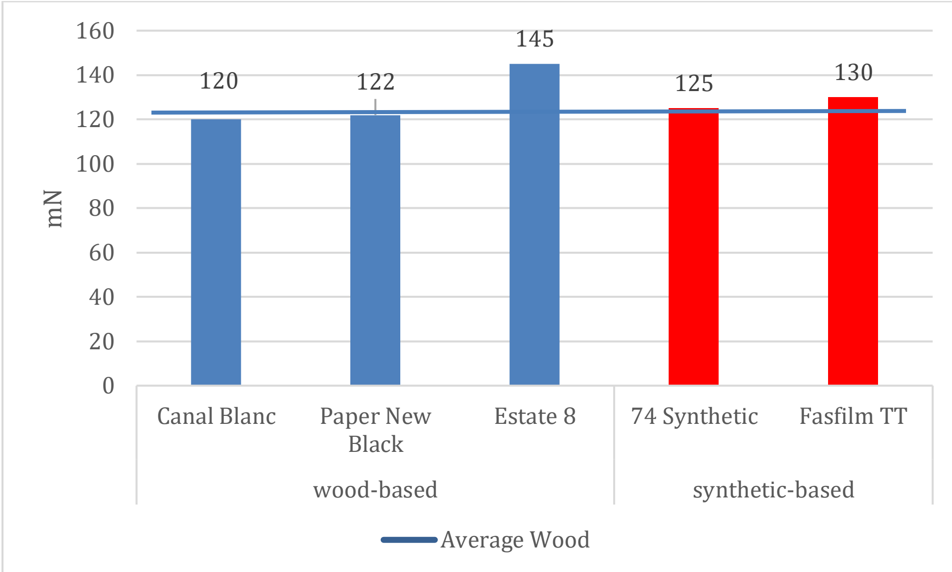

Figure 3. Tearing Resistance (MD) Synthetic v. Wood

The Tearing Resistance (MD) of the synthetic substrates falls within the benchmark range of wood-based substrates. Therefore, both synthetic substrates could be comparable to wood-based substrates in terms of Tearing Resistance in the Machine Direction.

As Figure 4 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tearing Resistance in the Cross Direction (CD) of 124 mN, 126 mN, and 152 mN, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Tearing Resistance in the CD of 131 mN and 134 mN, respectively.

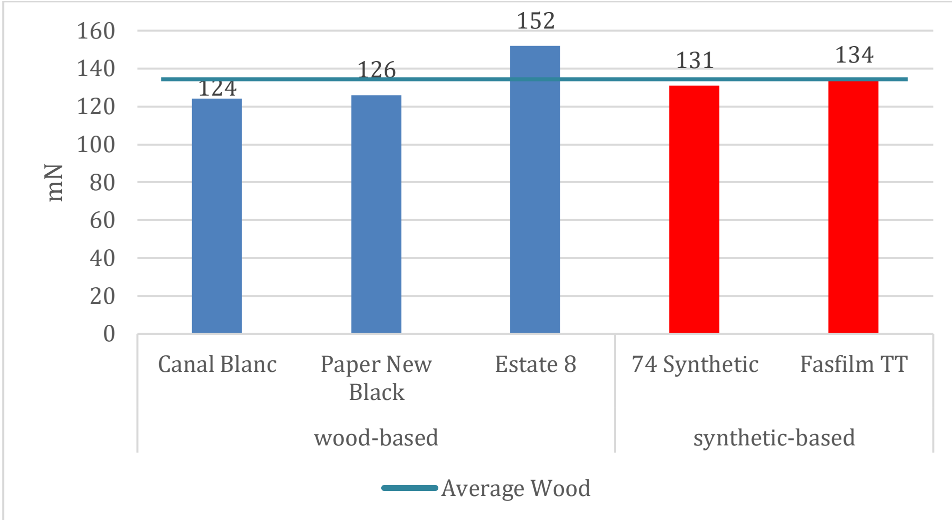

Figure 4. Tearing Resistance (CD) Synthetic v. Wood

The Tearing Resistance (CD) scores of the synthetic substrates fall within the benchmark range of wood-based substrates. Therefore, both synthetic substrates could be comparable to the wood-based substrates in terms of Tearing Resistance in the Cross Direction.

Cobb Test. A Cobb Test is measured on the Top Side (TS) and the Wire Side (WS) of the substrates. For a Cobb Test, a lower score is desirable (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). As Figure 5 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have a Cobb score on the Top Side (TS) of 24 g/m^2, 21 g/m^2, and 30 g/m^2, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have a Cobb score on the TS of 35 g/m^2 and 1 g/m^2, respectively.

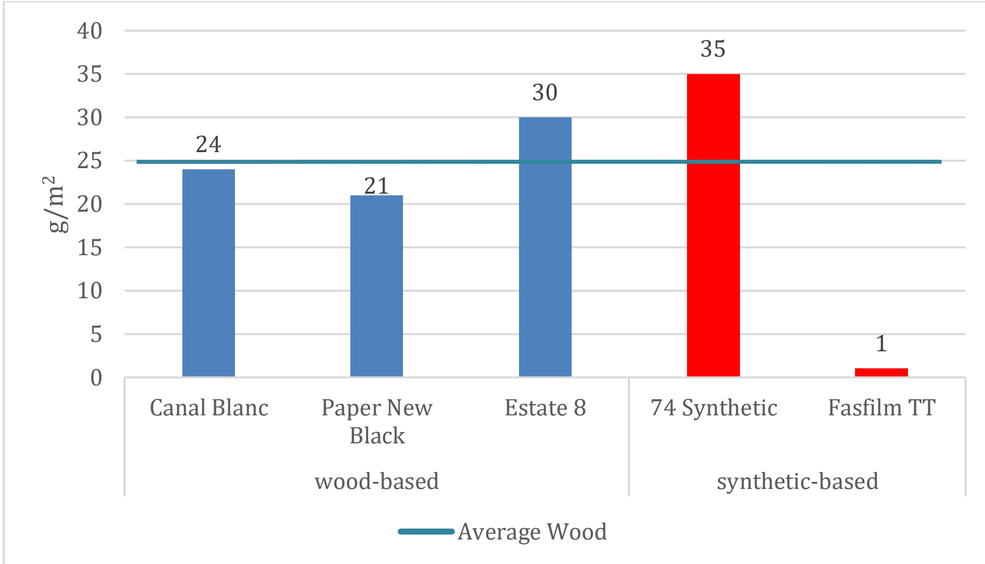

Figure 5. Cobb Test (TS) of Synthetic v. Wood

A Cobb Test (TS) of the synthetic papers indicates that one synthetic, Fasfilm TT, outperforms all the wood-based substrates. This could be expected as the Cobb Test is testing for water absorption; however, 74 Synthetic, another synthetic, has a score of 35 g/m^2, indicating greater absorption than any one of the wood-based substrates. This would seem to indicate that the two synthetic papers are formulated very differently. Thus, the Cobb Test (TS) indicates that Fasfilm TT could be an alternative for wood-based substrates in terms of the Cobb Test on the Top Side.

As Figure 6 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have a Cobb score on the Wire Side (WS) of 32 g/m^2, 22 g/m^2, and 22 g/m^2, respectively. The synthetic substrates, 74 synthetic and Fasfilm TT, have a Cobb score on the WS of 25 g/m^2 and 18 g/m^2, respectively.

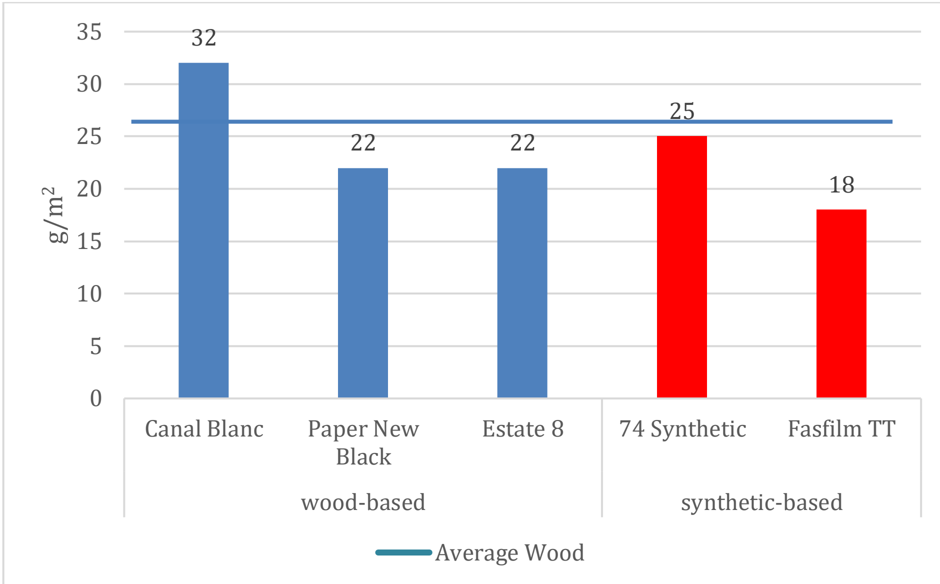

Figure 6. Cobb Test (WS) Synthetic v. Wood

A Cobb Test (WS) of the synthetic papers indicates that one synthetic, 74 Synthetic, falls within the benchmark range of the wood-based substrates. The other synthetic substrate, Fasfilm TT, falls below the benchmark range of the wood-based substrates. This suggests that Fasfilm TT could be used as a comparable substrate for wood-based substrates in terms of the Cobb Test on the Wire Side.

Optical Properties

For the Optical Property tests, Paper New Black, a wood-based substrate, is removed from the data. This is done because of the paper being black in contrast to the other white substrates tested.

Brightness. Brightness of a paper is calculated on a scale of 0-100, where the higher the number means the higher the brightness (Rogers, 2015). As Figure 7 illustrates, the wood-based substrates, Canal Blanc and Estate 8, have Brightness of 83.11% and 86.39%, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Brightness of 89.35% and 89.53%, respectively.

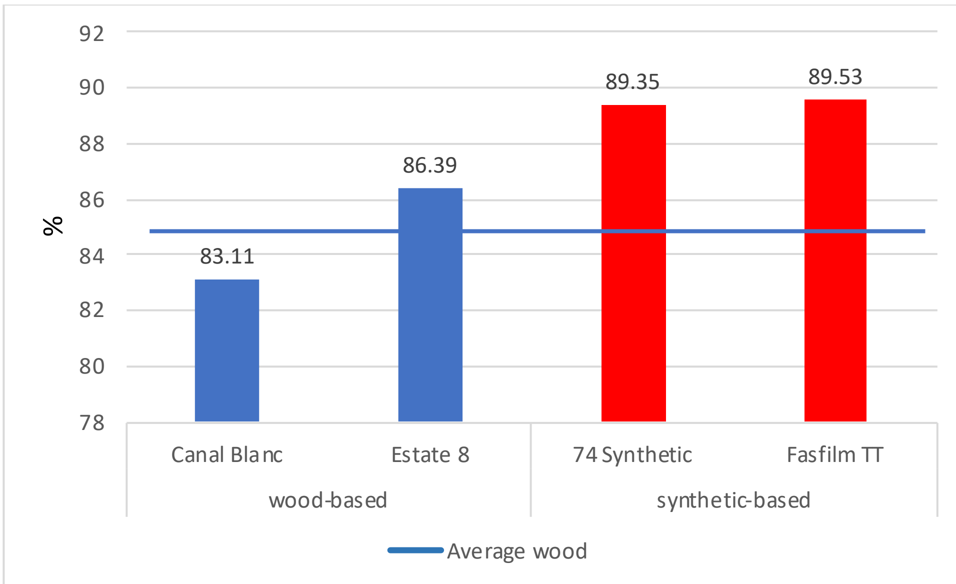

Figure 7. Brightness of Synthetic v. Wood

The Brightness of the synthetic substrates falls outside the benchmark range of the wood-based substrates, with both synthetics exhibiting higher measurements than the wood-based substrates. This suggests that the synthetics could perform better in terms of brightness than the wood-based substrates.

Opacity. As Figure 8 illustrates, the wood-based substrates, Canal Blanc and Estate 8, have Opacity of 94.81% and 93.32%, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Opacity of 93.51% and 90.44%, respectively.

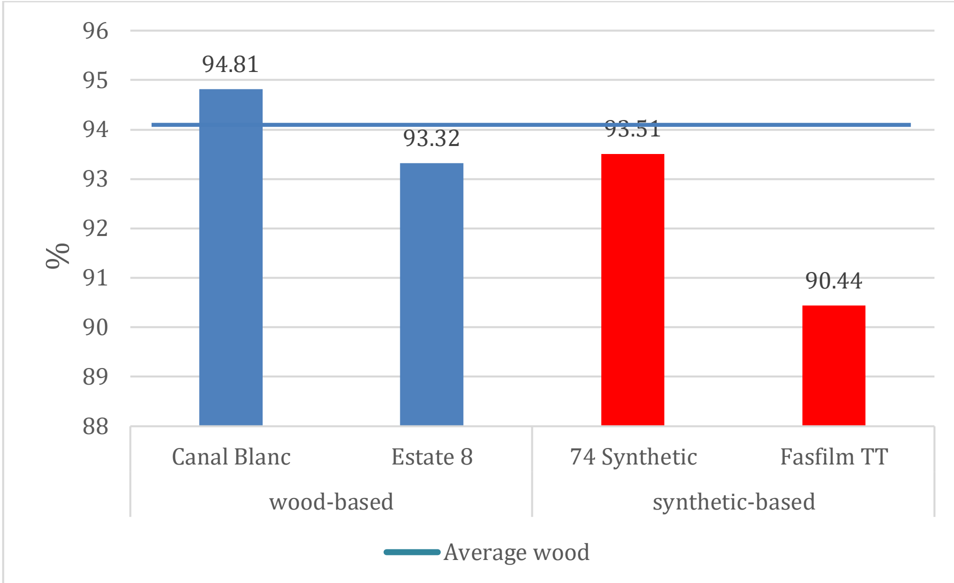

Figure 8. Opacity of Synthetic v. Wood

The Opacity of the synthetic papers indicates that one synthetic, 74 Synthetic, falls within the benchmark range of the wood-based substrates. The other synthetic substrate, Fasfilm TT, falls below the benchmark range of the wood-based substrates. A synthetic substrate, 74 Synthetic, could be considered as an alternative as it is within the benchmark range and is higher in terms of Opacity when compared to one of the wood-based substrates (Estate 8).

Research Question 2

How do the physical and optical properties of a selected stone-based paper compare with those of selected wood-based substrates for use as wine labels?

Physical Properties

Burst Strength. As Figure 9 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Burst Strengths of 69.51 psi, 64.01 psi, and 64.13 psi, respectively. The stone-based substrate has a Burst Strength of 47.99 psi.

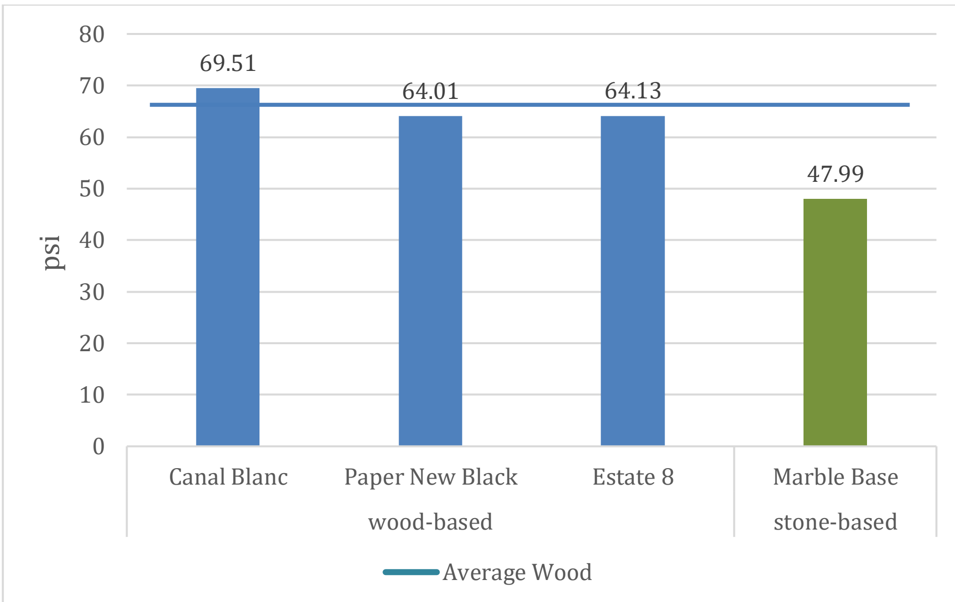

Figure 9. Burst Strength of Stone v. Wood

The Burst Strength of the stone-based substrate falls outside the lower benchmark range of wood-based substrates. This suggests that the wood-based substrates would perform better in terms of Burst Strength than the tested stone-based substrate. The lower performance of stone-based with regards to Burst Strength compared with wood-based substrates could be a factor in selecting a wine label substrate.

Tensile Strength. Tensile Strength is measured in the Machine Direction (MD) and the Cross Direction (CD). As Figure 10 illustrates, the wood-based substrates, Canal

Blanc, Paper New Black, and Estate 8, have Tensile Strength in the Machine Direction (MD) of 9.32 kN/m, 5.5 kN/m, and 9.2 kN/m, respectively. The stone-based substrate has Tensile Strength in the MD of 5.9 kN/m.

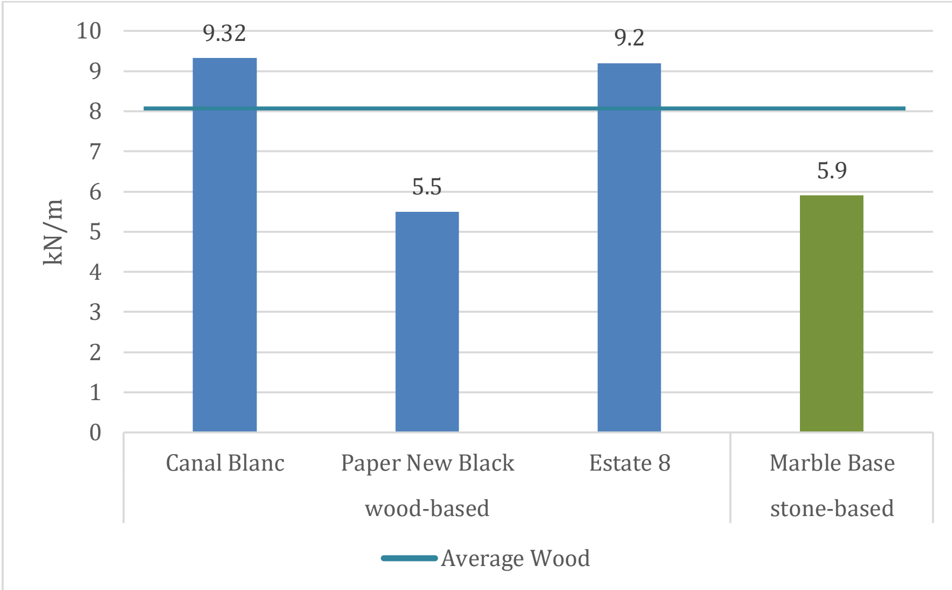

Figure 10. Tensile Strength (MD) of Stone v. Wood

The Tensile Strength (MD) of the stone-based falls within the benchmark range of wood-based substrates. This suggests that some wood-based substrates would perform better in terms of Tensile Strength than stone-based in the Machine Direction. However, the stone-based could be considered a reasonable alternative for wood-based substrates as it has a higher measurement than one of the wood-based substrates.

As Figure 11 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tensile Strength in the Cross Direction (CD) of 5.3 kN/m, 5 kN/m, and 8.5 kN/m, respectively. The stone-based substrate has Tensile Strength in the CD of 3.8 kN/m.

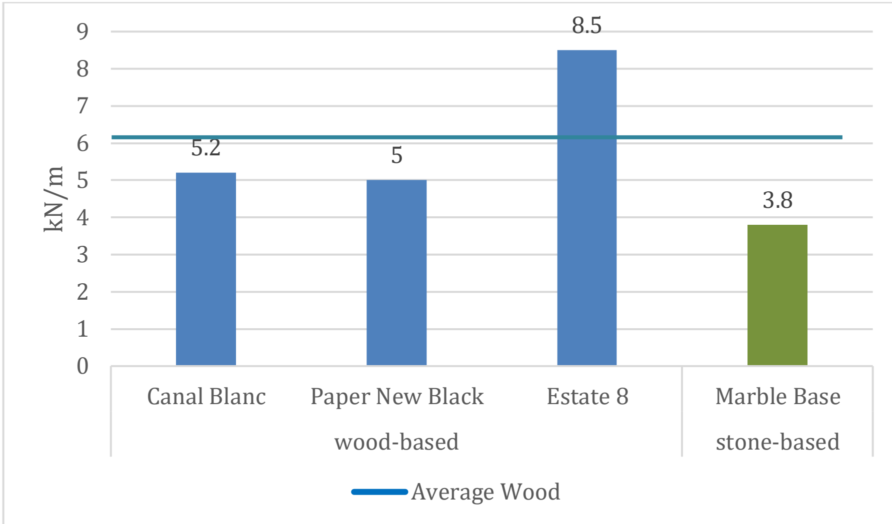

Figure 11. Tensile Strength (CD) of Stone v. Wood

The Tensile Strength (CD) of stone-based falls below the benchmark range of wood-based substrates. This suggests that the wood-based substrates would perform better in terms of Tensile Strength than stone-based in the Cross Direction.

Tearing Resistance. Tearing Resistance is measured in the Machine Direction (MD) and the Cross Direction (CD). As Figure 12 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tearing Resistance in the Machine Direction (MD) of 120 mN, 122 mN, and 145 mN, respectively. The stone-based substrate has Tearing Resistance in the MD of 54 mN.

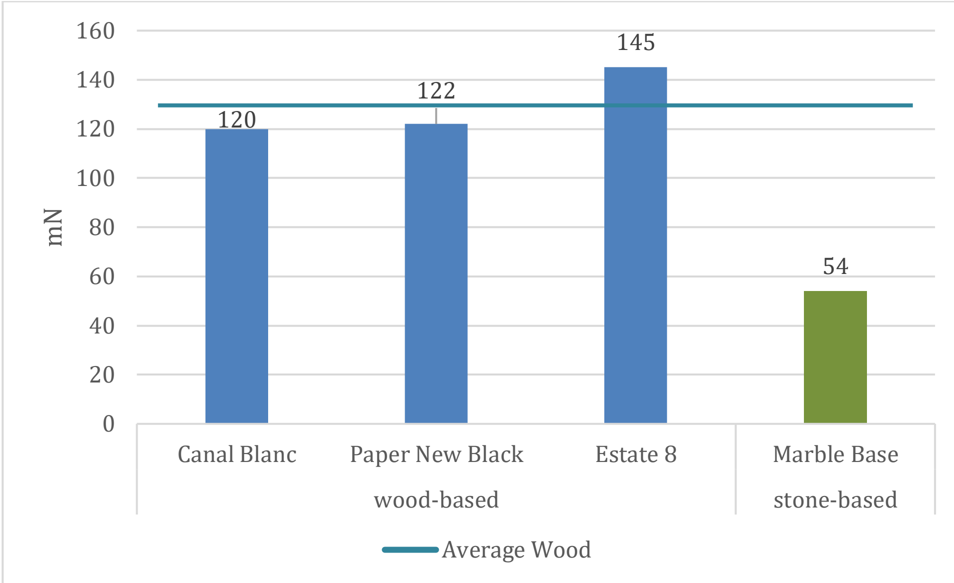

Figure 12. Tearing Resistance (MD) Stone v. Wood

The Tearing Resistance (MD) of the stone-based falls below the benchmark range of wood-based substrates. This suggests that the wood-based substrates would perform better in terms of Tearing resistance in the machine direction.

As Figure 13 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tearing Resistance in the Cross Direction (CD) of 124 mN, 126 mN, and 152 mN, respectively. The stone-based substrate has Tearing Resistance in the CD of 60 mN.

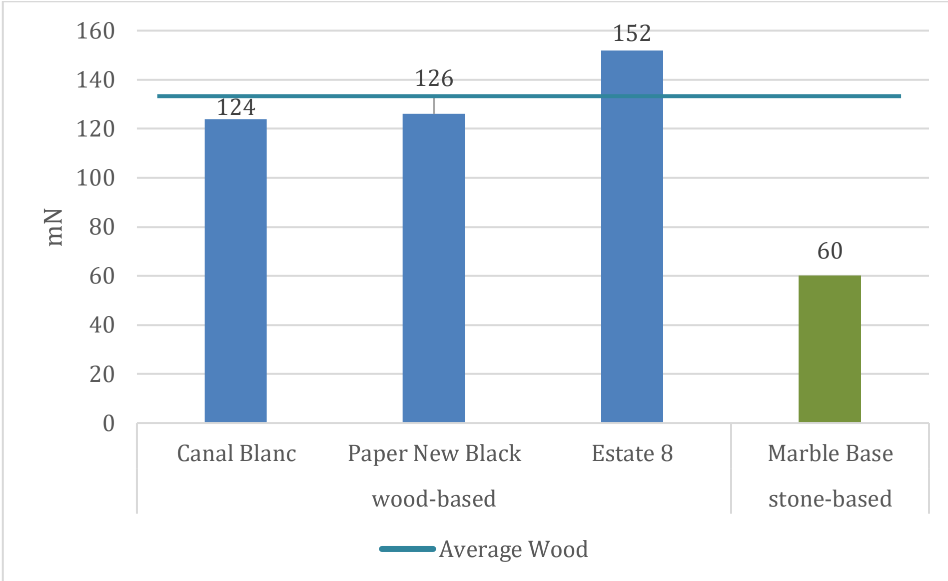

Figure 13. Tearing Resistance (CD) of Stone v. Wood

The Tearing Resistance (CD) of the stone-based substrate falls below the benchmark range of wood-based substrates. This suggests that the wood-based substrate would perform better in terms of Tearing Resistance in the cross direction.

Cobb Test. A Cobb Test is measured on the Top Side (TS) and the Wire Side (WS). For a Cobb Test, a lower score is desirable (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). As Figure 14 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have a Cobb score on the Top Side (TS) of 24 g/m^2, 21 g/m^2, and 30 g/m^2, respectively. The stone-based substrate has a Cobb score on the TS of 4.6 g/m^2.

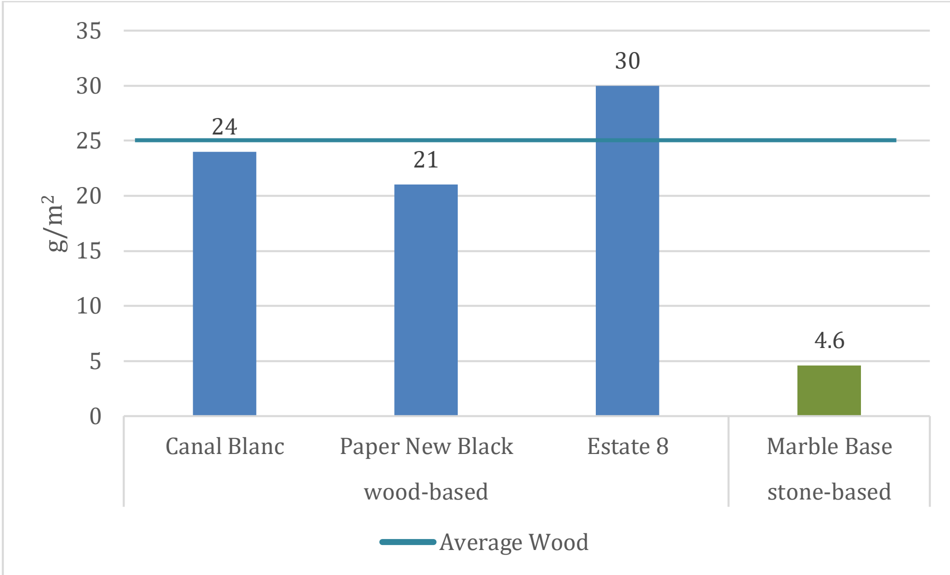

Figure 14. Cobb Test (TS) of Wood v. Stone

A Cobb Test (TS) of the stone-based falls below the benchmark range of wood-based substrates. This suggests that the stone-based substrate would perform better in terms of the Cobb Test than wood-based substrates on the top side.

As Figure 15 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have a Cobb score on the Wire Side (WS) of 32 g/m^2, 22 g/m^2, and 22 g/m^2, respectively. The stone-based substrate has a Cobb score on the WS of 26 g/m^2.

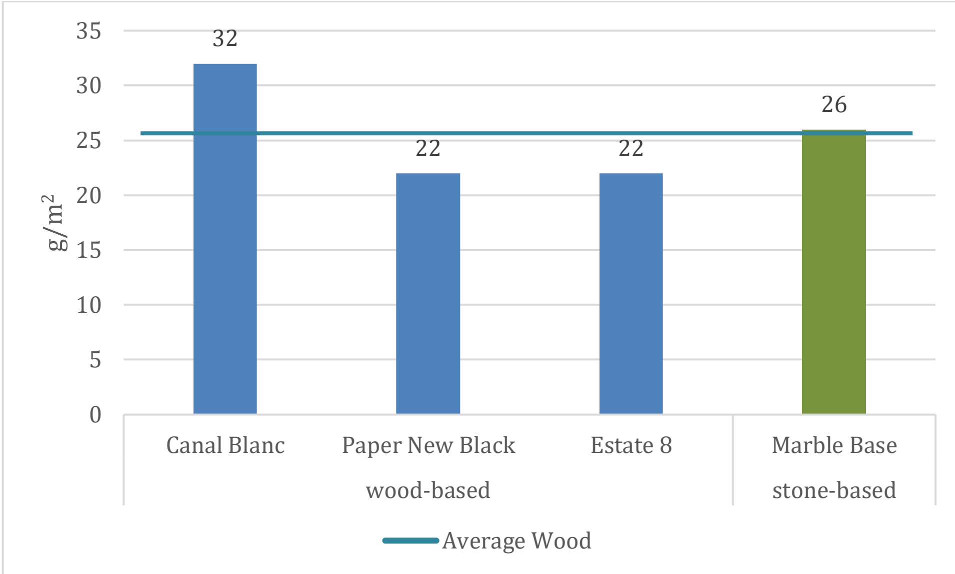

Figure 15. Cobb Test (WS) Stone v. Wood

A Cobb Test (WS) of the stone-based falls within the benchmark range of the wood-based substrates. This suggests that the wood-based substrates could perform better in terms of the Cobb Test than stone-based on the Wire Side. However, stone-based could be considered as a comparable alternative as the value of its Cobb score is lower than one of the wood-based substrates.

Optical Properties

For the Optical Property tests, Paper New Black, a wood-based substrate, is removed from the data. This is done because of the paper being black in contrast to the other white substrates tested.

Brightness. Brightness of a paper is calculated on a scale of 0-100, where the higher the number means the higher the brightness (Rogers, 2015). As Figure 16 illustrates, the wood-based substrates, Canal Blanc and Estate 8, have the Brightness of 83.11% and 86.39%, respectively. The stone-based substrate has Brightness of 82.13%.

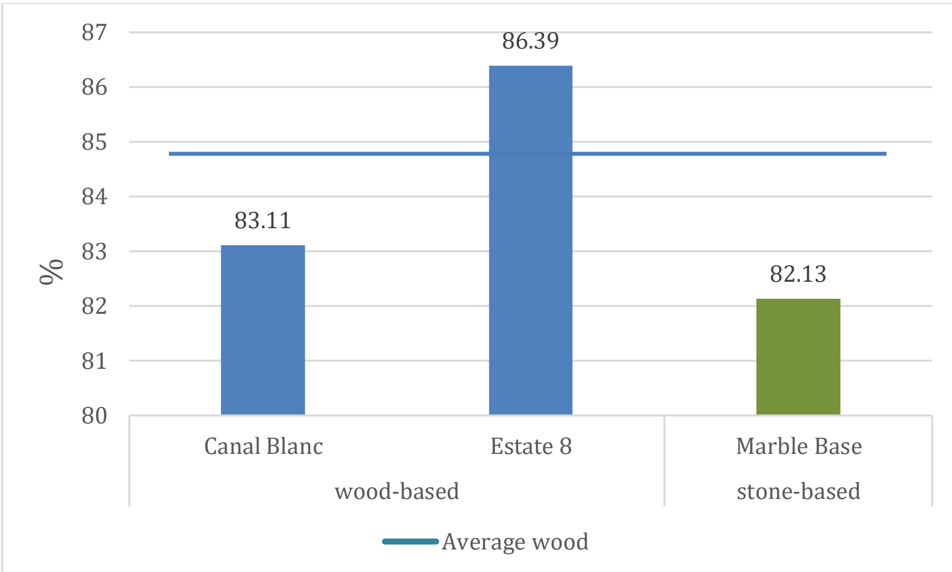

Figure 16. Brightness of Stone v. Wood

The Brightness of the stone-based falls below the benchmark range of wood-based substrates. This suggests that the wood-based substrates could present a better option in terms of Brightness than the stone-based substrate.

Opacity. As Figure 17 illustrates, the wood-based substrates, Canal Blanc and Estate 8, have Opacity of 94.81% and 93.32%, respectively. The stone-based substrate has Opacity of 92.43%.

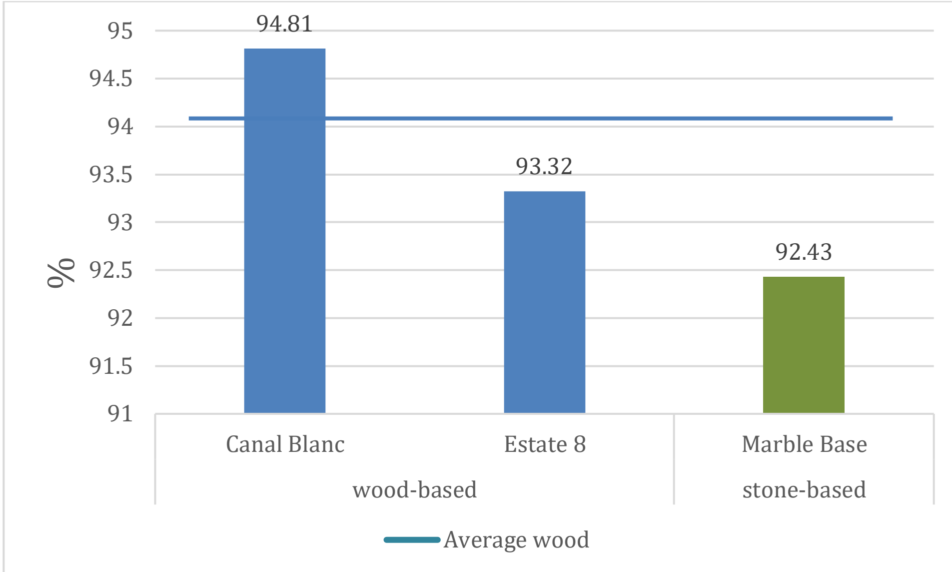

Figure 17. Opacity of Stone v. Wood

The Opacity of the stone-based substrate falls below the benchmark range of the wood-based substrates. This suggests that wood-based substrates could present a better option in terms of Opacity.

Discussion of Results

This part of the chapter discusses the overall conclusions of both the first and the second research questions.

Physical Properties

Burst Strength. Burst Strength can be important in wine labels, particularly in flexible packaging. As Figure 18 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Burst Strength of 69.51 psi, 64.01 psi, and 64.13 psi, respectively. The stone-based substrate has the burst strength of 47.99 psi. No burst strength could be determined for the synthetic substrates as the substrates kept stretching, making it not possible to measure burst strength on the instrument.

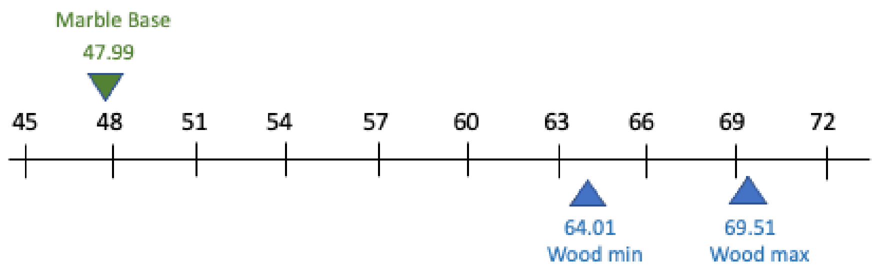

Figure 18. Burst Strength of Synthetic and Stone v. Wood

The Burst Strength of the stone-based substrate falls below the benchmark range of wood-based substrates. This suggests that the wood-based substrates would perform better in terms of Burst Strength. For synthetic substrates to be measured for Burst Strength, a different instrument should be considered and identified.

Tensile Strength. Tensile Strength can be very important in wine labels as it can help determine the resistance of the labels during application on the product. Tensile Strength is measured in the Machine Direction (MD) and the Cross Direction (CD). As Figure 19 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tensile Strength in the Machine Direction (MD) of 9.32 kN/m, 5.5 kN/m, and 9.2 kN/m, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have

Tensile Strength in the MD of 9.6 kN/m and 5.4 kN/m, respectively. The stone-based substrate has Tensile Strength in the MD of 5.9 kN/m.

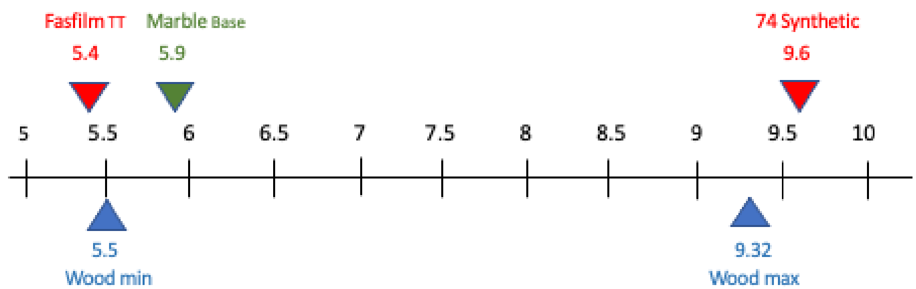

Figure 19. Tensile Strength (MD) for Synthetic and Stone v. Wood

The Tensile Strength (MD) of the synthetic-based substrates falls outside the benchmark of wood-based substrates, with one being lower than the benchmark range and one being higher; whereas, the stone-based substrate falls within the benchmark range. This suggests that the synthetic substrate, 74 Synthetic, could be considered as an alternative for wood-based substrates in terms of Tensile Strength in the machine direction. It also appears that the stone-based substrate could be used as a possible alternative.

As Figure 20 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tensile Strength in the Cross Direction (CD) of 5.2 kN/m, 5 kN/m, and 8.5 kN/m, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Tensile Strength in the CD of 5.6 kN/m and 3.5 kN/m, respectively. The stone-based substrate has Tensile Strength in CD of 3.8 kN/m.

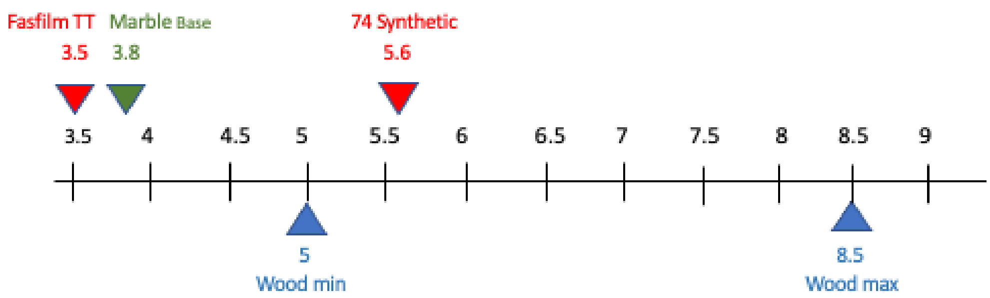

Figure 20. Tensile Strength (CD) for Synthetic and Stone v. Wood

The Tensile Strength (CD) of stone-based and one of the synthetic-based substrates, Fasfilm TT, falls below the benchmark range of the wood-based substrates. The other synthetic substrate, 74 Synthetic, falls within the benchmark range for wood-based substrates. This suggests that the wood-based substrates could perform better in terms of Tensile Strength than the synthetic and stone-based in the cross direction. However, the synthetic substrate, 74 Synthetic, can be considered as an alternative to the wood-based substrates as it measured higher than Paper New Black.

Tearing Resistance. Tearing Resistance can be very important in wine labels as it can help determine that labels will not tear on applying tension during the release from the liner and will not tear when they are soaked in an ice-bucket. Tearing Resistance is measured in the Machine Direction (MD) and the Cross Direction (CD). As Figure 21 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tearing Resistance in the Machine Direction (MD) of 120 mN, 122 mN, and 145 mN, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Tearing

Resistance in the MD of 125 mN and 130 mN, respectively. The stone-based substrate has Tearing Resistance in the MD of 54 mN.

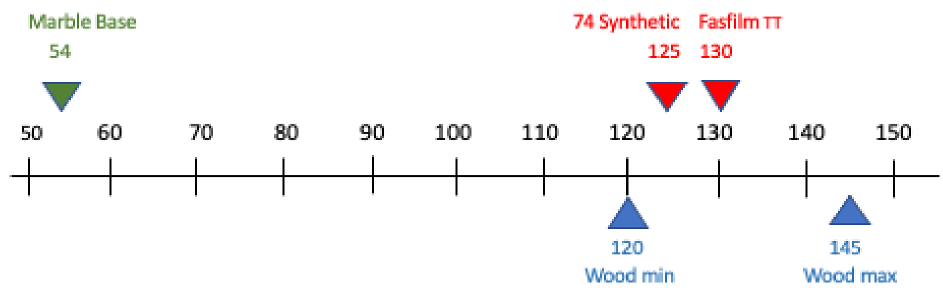

Figure 21. Tearing Resistance (MD) of Synthetic and Stone v. Wood

The Tearing Resistance (MD) of the stone-based substrate falls below the benchmark range of the wood-based substrates, and the synthetic-based substrates fall within the benchmark range. This suggests that the synthetic substrates could be considered as alternatives for Tearing Resistance in the Machine Direction.

As Figure 22 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have Tearing Resistance in the Cross Direction (CD) of 124 mN, 126 mN, and 152 mN, respectively. The synthetic-based substrates, 74 Synthetic and Fasfilm TT, have Tearing Resistance in the CD of 131 mN and 134 mN, respectively. The stone-based substrate has Tearing Resistance in the CD of 60 mN.

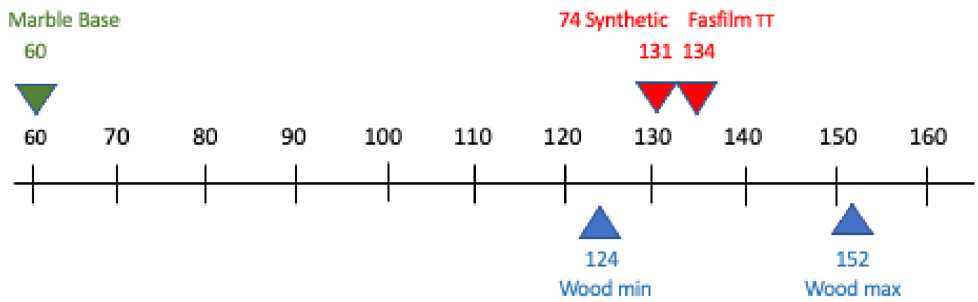

Figure 22. Tearing Resistance (CD) for Synthetic and Stone v. Wood

The Tearing Resistance (CD) of the stone-based substrate falls below the benchmark range of the wood-based substrates, and the synthetic substrates falls within the benchmark range. This suggests that the synthetic substrates could be considered as alternatives for Tearing Resistance in the cross direction.

Cobb Test. A Cobb Test can be very important in wine labels as it can help determine that labels do not absorb water when they are placed in an ice-bucket. This characteristic is important, especially for self-adhesive labels. For the Cobb Test, a lower score is desirable (Akash K S, personal communication with a representative from Avery Dennison, India, December 1, 2020). A Cobb Test is measured on the Top Side (TS) and the Wire Side (WS). As Figure 23 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have a Cobb score on the Top Side (TS) of 24 g/m^2, 21 g/m^2, and 30 g/m^2, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have a Cobb score on the TS of 35 g/m^2 and 1 g/m^2, respectively. The stone-based substrate has a Cobb in the TS of 4.6 g/m^2.

Figure 23. Cobb Test (TS) for Synthetic and Stone v. Wood

A Cobb Test (TS) of both the stone-based substrate and one of the synthetic-based substrates falls below the benchmark range of wood-based. This suggests that the synthetic substrate, Fasfilm TT, and the stone-based substrate could be considered as alternatives for the wood-based substrates. However, 74 Synthetic falls beyond the benchmark range, and therefore on this characteristic would not be considered as an alternative for the wood-based substrates.

As Figure 24 illustrates, the wood-based substrates, Canal Blanc, Paper New Black, and Estate 8, have a Cobb score on the Wire Side (WS) of 32 g/m^2, 22 g/m^2, and 22 g/m^2, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have a Cobb score on the WS of 25 g/m^2 and 18 g/m^2, respectively. The stone-based substrate has a Cobb score on the WS of 26 g/m^2.

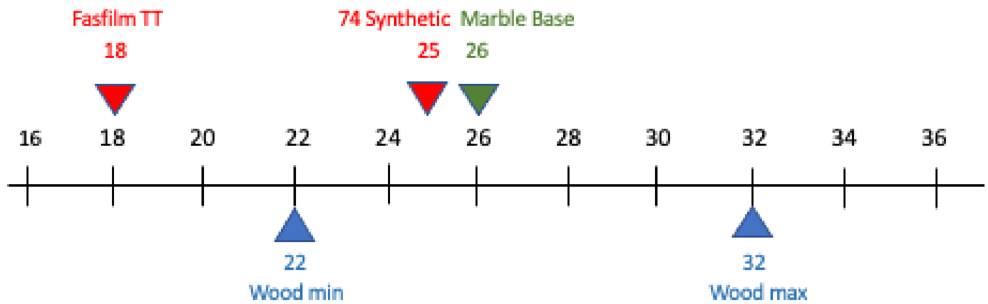

Figure 24. Cobb Test (WS) for Synthetic and Stone v. Wood

The Cobb Test (WS) scores of both the stone-based and one of the synthetic substrates, 74 Synthetic, fall within the benchmark range of wood-based, whereas the other synthetic substrate, Fasfilm TT, falls below the benchmark range of wood-based substrates. This suggests that both synthetics and the stone-based substrates could be considered as alternatives based on the Cobb Test for the Wire Side, although Fasfilm TT appears most resistant to water absorption.

Optical Properties

For the Optical Property tests, Paper New Black, a wood-based substrate, is removed from the data. This is done because of the paper being black in contrast to the other white substrates tested.

Brightness. Brightness of a paper is calculated on a scale of 0-100, where the higher the number means the higher the brightness (Rogers, 2015). As Figure 25 illustrates, the wood-based substrates, Canal Blanc and Estate 8, have Brightness of

83.11% and 86.39%, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Brightness of 89.35% and 89.53%, respectively. The stone-based substrate has Brightness of 82.13%.

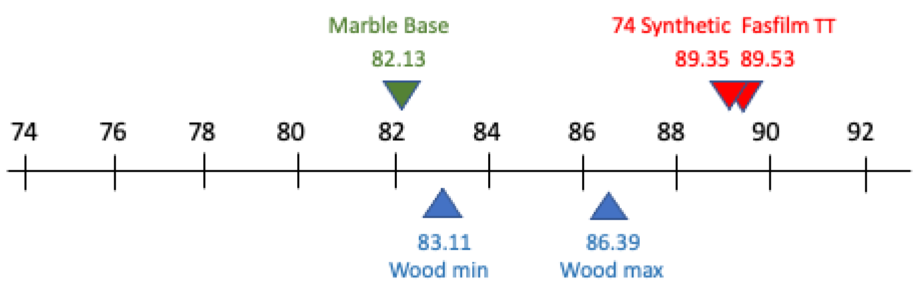

Figure 25. Brightness of Synthetic and Stone v. Wood

The Brightness of both the synthetic substrates exceeds the benchmark range of the wood-based substrates; therefore, both synthetic substrates can be considered as alternatives in terms of Brightness. The stone-based, however, falls below the benchmark range and would not be considered as an alternative for this property.

Opacity. Measuring opacity in wine labels is not critical as most of the substrates are opaque except for specialty substrates like Vellum. As Figure 26 illustrates, the wood-based substrates, Canal Blanc and Estate 8, have Opacity of 94.81% and 93.32%, respectively. The synthetic substrates, 74 Synthetic and Fasfilm TT, have Opacity of 93.51% and 90.44%, respectively. The stone-based substrate has Opacity of 92.43%

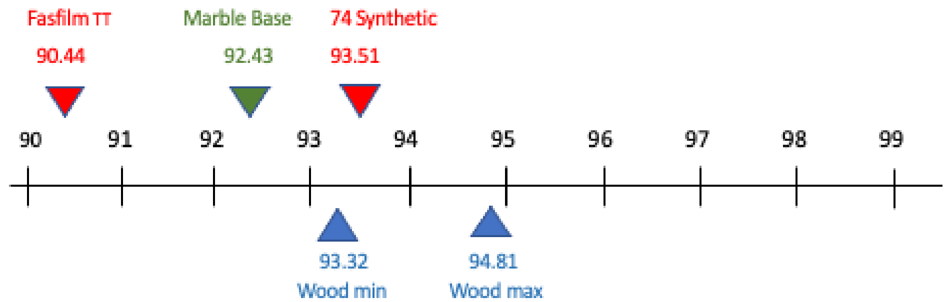

Figure 26. Opacity of Synthetic and Stone v. Wood

The Opacity of both the stone-based and one of the synthetic substrates, Fasfilm TT, falls below the benchmark range of the wood-based substrates, and the other synthetic substrates, 74 Synthetic, falls within the benchmark of wood-based substrates. Therefore, 74 Synthetic can be considered as an alternative for wood-based substrates in terms of Opacity.

Overall Analyses

Table 3, as shown below, displays the alternative substrates for the commonly used wood-based substrates. The selection of substrates as alternatives to wood-based was based on two rules: (a) The test substrate must fall within the benchmark range of the wood-based substrates, and (b) If a substrate measurement does not fall within the benchmark range, it must have a score that shows an improvement over the benchmark range. Based on these two rules, the alternative substrates to wood-based were identified.

Burst Strength

No alternative substrates could be identified in terms of Burst Strength because the synthetic substrates that were tested stretched and did not burst; whereas, the stone-based substrate fell below the benchmark range of the wood-based substrates.

Tensile Strength

Considering Tensile Strength in both the Machine Direction and in the Cross Direction indicates that 74 Synthetic can be an alternative to wood-based substrates because it exceeded the benchmark range in the Machine Direction and is within range in the Cross Direction.

Tearing Resistance

Considering Tearing Resistance in both the Machine Direction and in the Cross Direction indicates that the synthetic substrates can be considered as an alternative as they measured within the benchmark range in both the Machine Direction and the Cross Direction.

Cobb Test

Considering the Cobb Test on both the Top Side and the Wire Side indicates that Fasfilm TT can be considered as an alternative as it measured below the benchmark range (an improvement) for the Cobb Test on both the Top Side and the Wire Side.

Brightness

Brightness measurements of the substrates indicate that Fasfilm TT and 74 Synthetic can be considered as alternatives to wood-based substrates as they both measured higher than the benchmark range in terms of Brightness.

Opacity

Opacity measurements of the substrates indicate that 74 Synthetic can be considered as an alternative to wood-based substrates as it falls towards the higher end within the benchmark range.

Table 3

Overall Chart of Results

Property Name	Alternatives for Wood-based
Burst Strength	-
Tensile Strength	74 Synthetic
Tearing Resistance	Fasfilm TT, 74 Synthetic
Cobb Test	Fasfilm TT
Brightness	Fasfilm TT, 74 Synthetic
Opacity	74 Synthetic

As shown in Table 3, 74 Synthetic and Fasfilm TT were found to be alternatives for the wood-based substrates as the synthetic substrates together led in five of the five properties for which they could be tested.

Chapter 6
Discussion and Conclusion

Wine labels are one of the most important factors that attract customers to a particular wine bottle. Most of the studies performed on wine labels have been marketing research focused utilizing eye-tracking and surveys (Elliot & Barth, 2012; Kelley, Hyde, & Bruwer, 2015; Rocchi & Stefani, 2006). This current study originated from an opportunity to expand on the limited material science research published about wine label substrates. It considered the most commonly used wine labels that are made from wood-based substrates in the European and Indian markets, and these wood-based substrates were then used to create benchmarks for optimal physical and optical wine label properties. This study explored the possibility of different substrates that could replace the commonly used label substrates.

This study was conducted because the wine industry in Europe and India primarily use wood-based substrates for wine bottle labels and have seemingly not adopted or seriously considered other substrates made from synthetics or stone. Stone paper is especially interesting because it has not been widely researched academically though there are positive advertising claims about it (Palladino, 2013).

Substrates' Benchmark Performance

By using the characteristics of wood-based substrates as benchmarks, this study sought to identify ideal alternative substrates that would have similar physical and optical properties. The benchmarks were as follows:

- Burst Strength, between 64.01 psi and 69.51 psi
- Tensile Strength
    - Machine Direction, between 5.5 kN/m and 9.32 kN/m
    - Cross Direction, between 5.0 kN/m and 8.5 kN/m
- Tearing Resistance
    - Machine Direction, between 120 mN and 145 mN
    - Cross Direction, between 124 mN and 152 mN
- Cobb Test
    - Top Side, between 21 g/m^2 and 30 g/m^2
    - Wire Side, between 22 g/m^2 and 32 g/m^2
- Brightness, between 83.11% and 86.39%
- Opacity, between 93.32% and 94.81%

Using these benchmark ranges to compare the selected substrates, this study identified no stone or synthetic substrate that was within all benchmark ranges for every property tested. Some substrates had one or two properties that were within the benchmark ranges or even performed better.

The stone-based substrate did not fully fall within the benchmark range (except for the MD in Tensile Strength and WS in the Cobb Test) or exceed the benchmark in a positive direction in any of the properties tested. Although stone paper is usually promoted as being tear-resistant and water-resistant, the tests used in this study did not support these claims.

The properties tested for synthetic substrates fell within or exceeded some of the benchmark ranges of the wood-based substrates. However, between the two synthetic substrates tested, 74 Synthetic seemed to perform well for Tensile Strength, Tearing Resistance, Brightness, and Opacity; whereas, the other synthetic substrate, Fasfilm TT, performed well in the Cobb Test, Tearing Resistance, and Brightness. This makes the 74 Synthetic substrate slightly better than Fasfilm TT as an alternative for the most used wood-based papers selected for the study.

Limitations of the Study

Although this study provided helpful information about the comparison of substrates for wine labels, the study has some limitations that should be acknowledged.

Because the scope of this study involved a limited number of substrates and tested properties, the answers to the Research Questions were limited to the variables in the study; the results cannot be statistically generalized to all wood-based, synthetic-based, and stone-based substrates.

Only two synthetic substrates and one stone-based substrate were used for the study. This was done because of the limited resources available to acquire substrate samples. This small sample size did not allow for the overall characterization of the substrates as possible alternative to the commonly used wood-based substrates, thus inhibiting wide-scale generalizability of the results.

Only four physical properties and two optical properties were tested for this study. Increasing the number of the properties tested to measure such attributes as print quality and ink adhesion would provide additional useful information enabling more thorough comparison of substrates.

Opportunities for Future Research

This study considers an area that has not been extensively researched. The following details suggestions for future research.

Stone paper is a substrate with a complicated environmental impact that involves contradicting claims and opinions (Palladino, 2013). For example, stone paper manufacturers promote the tear resistance as one of the main properties of their product; however, the result of this study unexpectedly showed that the tested wood-based paper had a higher tear resistance than the stone paper. Investigating these differences could be an interesting topic of research.

Although this study focused mainly on the physical and optical properties of the selected substrates, a quantitative and qualitative analysis of how these substrates perform as printed wine labels could be beneficial. A study of the inks and printing devices that work well with these substrates could be particularly helpful in both production and design decisions concerning wine labels.

Identifying the most-used wine label substrates in other countries or regions besides India and Europe, increasing the number of sample substrates, replicating the methodology of the current study, and possibly introducing statistical analysis of the test measurements are all areas that could lead to future research that would be useful to the wine label decision makers.

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